Business Process Modelling in Demand-Driven Agri-Food Supply Chains

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Abstract

Agri-food companies increasingly participate in demand-driven supply chains that are able to adapt flexibly to changes in the marketplace. The objective of this presentation is to discuss a process modelling framework, which enhances the interoperability and agility of information systems as required in such dynamic supply chains. The designed framework consists of two parts: an object system definition and a modelling toolbox. The object system definition provides a conceptual definition of business process in demand-driven supply chains from a systems perspective. It includes an application of the Viable Systems Model of Stafford Beer to supply chains, and classifications of business processes, control systems and coordination mechanisms. The modelling toolbox builds on the terminology and process definitions of SCOR and identifies three types of process models:

i) *Product Flow Models:* visualize the allocation of basic transformations to supply chain actors and the related product flows from input material into end products (including different traceability units based on the GS1 Global Traceability Standard);
ii) *Thread Diagrams:* visualize how order-driven and forecast-driven processes are decoupled in specific supply chain configurations (positions Customer Order Decoupling Points), and how interdependences between processes are coordinated;
iii) *Business Process Diagrams*: depict the sequence and interaction of control and coordination activities (as identified in Thread Diagrams) in BPMN notation.

The framework is applied to several agri-food sectors, in particular potted plants and fruit supply chains. The main benefits are:

i) It helps to map supply chain processes, including its control and coordination, in a timely, punctual and coherent way;
ii) It supports a seamless translation of high-level supply chain designs to detailed information engineering models;
iii) It enables rapid instantiation of various supply chain configurations (instead of dictating a single blueprint);
iv) It combines sector-specific knowledge with reuse of knowledge provided by generic cross-industry standards (SCOR, GS1).

1 Introduction

Agri-food companies operate in a complex and dynamic environment. Driving forces for change are diverse, and include:

- Increasing consumer concerns about food safety, and as a consequence fast changing food safety legislation and stringent quality requirements;
- Public concerns on effects of bio-industrial production;
- Increasing unpredictability of consumer demand;
- Globalization and liberalization of markets and as a consequence intensification of competition;
- More specific demand requirements to products with respect to the physical properties, packaging and labelling and service level;
- Fast advances in (information) technology;
- High pace of food innovations resulting in shorter product life cycles.

In order to sustain competitive advantage in this turbulent business environment, it is widely recognized that agri-food companies have to participate more and more in demand-driven supply chains that are able to adapt flexibly to changes in the marketplace. A *supply chain* is a connected series of business processes performed by a network of interdependent organizations working together to control, manage and improve the flow of materials and information from suppliers to ultimate consumers (adapted from (Van der Vorst, 2000, Christopher, 2005). A *demand-driven* supply chain is a supply chain that senses and reacts to real-time demand information of the ultimate consumer and meets those varied and variable demands in a timely and cost-effective manner (adapted from (Kohli and Jaworski, 1990, Vollmann *et al.*, 2000, Cecere *et al.*, 2004). Implementation of such supply chains is a complex task (Selen and Soliman, 2002). It requires products and business processes, including the network of producers and distributors, to be continuously adjusted to customer requirements.

Information systems are vital enablers of dynamic demand-driven supply chains. According to (Christopher, 2000), agile supply chains are information-based rather than inventory-based. They aim to share supply chain information be shared timely and subsequently the early alerted firms respond quickly to changes in demand or supply (Lee and Whang, 2000, Li *et al.*, 2007). The need for timely information sharing especially requires interoperability of the information systems of the involved companies. Interoperability is the ability for two systems to understand one another and to use one another's functionality (Chen *et al.*, 2008). The need for quick response requires agile information systems that support the flexibility to deal with unexpected changes in the business processes. Information system agility can be defined as the ability to quickly identify needed changes in information processing functionalities and thereafter to implement changes rapidly and efficiently (Lui and Piccoli, 2007).

Recently, information technology has made important progress to enhance interoperable and agile information systems, particularly by the development towards Service-Oriented Architecture (SOA). In a SOA approach, business process models are leading in routing event data amongst multiple software components that are packaged as interoperable web services (Erl, 2005). Consequently, new or adapted business processes can be supported without changing applications and the underlying infrastructure. Moreover, information systems can be quickly connected to new partners.

The leading role of business processes puts the emphasis on process models as central means for achieving the required interoperability and agility of information systems in agri-food supply chains. As a consequence, it must be possible to design new or adjusted business process models rapidly and at low costs. This can be achieved by reusing knowledge captured in reference process models. In demand-driven supply chains, reference process models should support the diversity of configurations in agri-food industry. Standard blueprints ('one size fits all') do not comply with such an approach. In contrast, (Verdouw *et al.*, 2010) argue that reference models should be set-up as configurable models that enable rapid instantiation of specific supply chain configurations. However, such models are not yet available in the agri-food domain.

The objective of this paper is to discuss a process modeling framework, which enhances the interoperability and agility of information systems as required in such dynamic supply chains. The framework consists of a conceptual view with respect to the field of interest and a toolbox for modelling supply chain processes from a repository of standard building blocks. In this paper we highlight the main findings of the designed framework. These findings are based on a number of other papers from on-going PhD-research connected to several pilot projects in which results are being applied to practice.

The remainder of this paper is organized as follows. In section 2, we first describe the applied research method. Subsequently, the next sections present the designed modelling framework. Section 3 describes a conceptual definition of the modelling object from a systems perspective. Section 4 introduces a modelling framework for designing reference process models in demand-driven agri-food supply chains. Section 5 illustrates the application of the framework by discussing case study results. To conclude, section 6 discusses the implications for policy and business.

2 Research approach / methodology

The research used a design-oriented research methodology, which is typically involved with "how" questions, i.e. how to design a model or system that solves a certain problem (Hevner *et al.*, 2004, Van Aken, 2004). The research applied a design-testing approach (comparable to theory testing methods in traditional empirical science, *cf.(Eisenhardt, 1989)*. In such an approach, first generic design knowledge is developed based on deductive reasoning, and after that the applicability of the design is tested. We applied the Generic Systems Approach as core method for deductive reasoning (amongst others (Bertalanffy, 1950, Beer, 1981, Malone and Crowston, 1994, In 't Veld, 2002). For testing, we have chosen in this paper for a case study approach. Consequently, the research is organized as follows.

First, Supply Chain Management literature was reviewed to define supply chains and to identify main elements of supply chain systems. We described supply chains from a systems perspective, because this provides a basis for consistently modelling interactions between processes. Based on the literature study, basic design requirements for reference process models in demand-driven agri-food supply chains are defined.

Second, we conducted an investigation of existing reference models for Production and Supply Chain Management. As (Thomas, 2006) argues, user-side acceptance is an important characteristic of reference information models. Therefore the investigation focussed on reference models which are widely acknowledged and applied in business community. These models were selected from existing surveys (Belle, 2002, Fettke and Loos, 2003, Fettke *et al.*, 2005) and additional literature search. The investigation is done by desk study and expert interviews with reference model developers and implementation consultants. The results were used to assess how close existing reference models meet the addressed requirements in demand-driven supply chains.

Third, we have designed a generic framework for modelling business process in demand-driven supply chains. Building on the investigation results, we have chosen the SCOR-model

as a basis for this design (SCC, 2008). SCOR is acknowledged as the most comprehensive supply chain process model and as a widely accepted common language in supply chain design (Huan *et al.*, 2004, Lambert *et al.*, 2005).
Last, the designed generic modelling framework is tested by applying it to different agri-food sectors, in particular potted plants and fruit supply chains. Several multiple case studies have been done. The primary data are in-depth interviews with key representatives of the involved case study firms. Every case study follows an action-based regulative cycle of problem analysis, design, and implementation (Van Strien, 1997). After that, the case study results are abstracted to reusable models that are incorporated in the framework.

Next sections highlight the main findings by subsequently discussing:

i) A conceptual definition of the modelling object from a systems perspective;
ii) A modelling framework for designing reference process models;
iii) Applications of the framework in agri-food industry.

3 Conceptual definition of the modelling object from a systems perspective

According to (Lambert and Cooper, 2000), supply chain systems comprise three main elements: i) the supply chain network structure of cooperating actors, ii) the supply chain business processes that are performed by these actors, and iii) the management of these processes. The management of supply chain processes can be further categorised by applying the Viable System Model (VSM) (Beer, 1981, Beer, 1984). This is a cybernetic model, which sets out to explain how systems are viable, that is capable of independent existence. The VSM is composed of five interacting subsystems:

- *System 1 (implementation)*: network of subsystems each consisting of an operational part interacting with its environment (productive unit) and a management part ensuring steady-state (control);
- *System 2 (coordination)*: allows the primary activities of operational subsystems (system 1) to communicate and align control. Furthermore, it enables System 3 to monitor the activities within System 1;
- *System 3 (regulation)*: establishes the rules, resources, rights and responsibilities of System 1 and provides an interface with Systems 4/5. In addition, System 3* is a sporadic audit which bypasses system 2 for a greater flexibility and timeliness.
- *System 4 (intelligence)*: looks outwards in order to monitor how the organisation needs to be adapted to remain viable and accordingly innovates the system towards new equilibriums;
- System 5 (*policy*): makes overall decisions to balance demands from different parts of the organisation and steers the organisation as a whole.

Figure 1 represents a supply chain as a system of interacting viable organisations

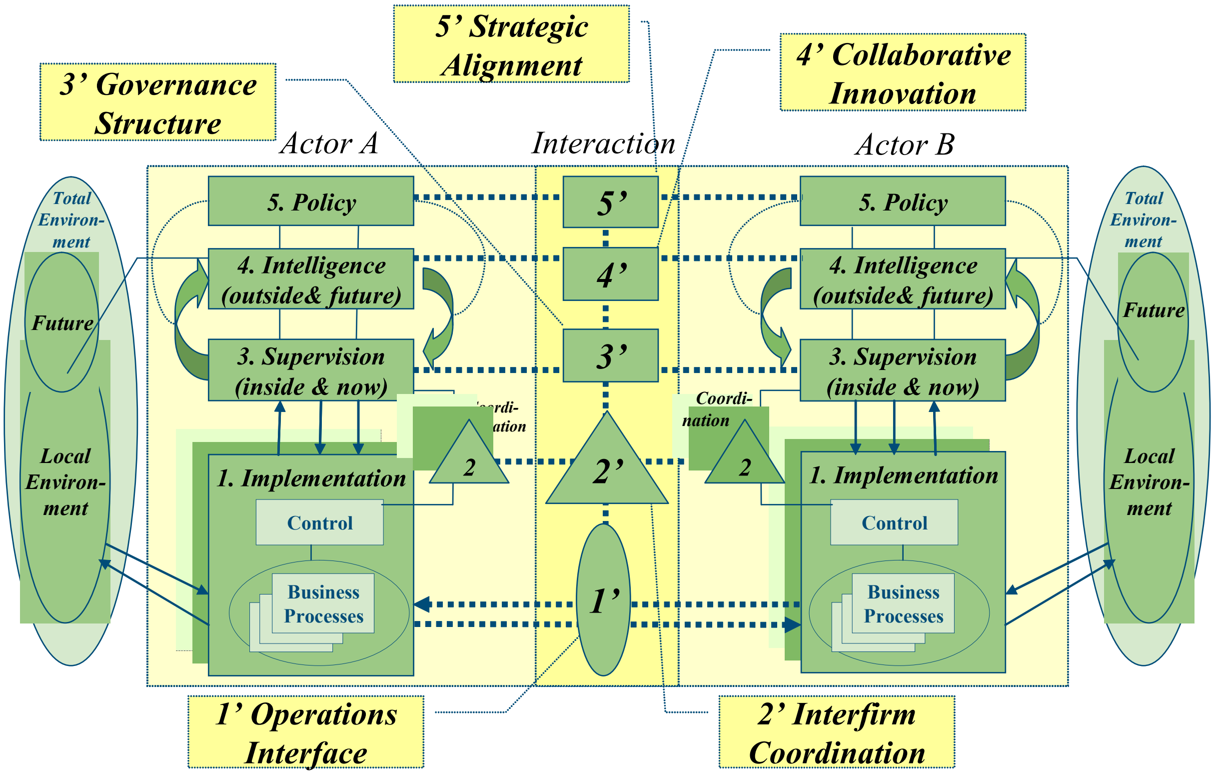

Figure 1. Viable System Model of a supply chain system (based on Beer 1981; Beer 1984)

The figure shows that a supply chain is a connected series of business processes performed by numerous autonomous companies. According to the different subsystems in the Supply Chain Viable System Model, there can be identified five types of interfirm interactions:

1. *Operations Interface* (systems 1 interaction): operational exchange of products, transactions and inherent information between different business processes and control of the involved actors;
2. *Interfirm Coordination* (systems 2 interaction): alignment of firm control requirements in order to manage dependencies between integrated systems 1 of the involved actors;
3. *Governance Structure* (systems 3 interaction): connects actors in the network by establishing relations and arrangements about allocation of property and decision rights, and risk and rewarding mechanisms. Three basic governance structures can be distinguished: markets, hierarchies and networks as a hybrid form;
4. *Collaborative Innovation* (systems 4 interaction): sharing relevant outside-information in an open innovation approach that leverages internal and external sources of ideas for product, process, marketing and organisational innovations;
5. *Strategic Alignment* (systems 5 interaction): comparing strategies of the involved actors and adaptation in order to prevent strategic mismatches.

Supply Chain Management primarily focuses on the operational integration of business processes, i.e the Operations Interface and Interfirm Coordination. Consequently, the main concepts of supply chain systems are business processes (performed by a network of firms), control and coordination. Below, these concepts will be further be defined and classified.

A *BUSINESS PROCESS* is a set of logically related tasks performed to achieve a defined business outcome (Davenport and Short, 1990). Business processes can be subdivided into primary processes that directly add value to products and supporting processes(Porter and

Millar, 1985). However, from a supply chain perspective, both the creation of value in transformations and the transfer of value in transactions are important (Diederen and Jonkers, 2001). In supply chains, transformations are performed by numerous firms, especially if there is a high degree of specialisation. This requires that products are transferred between firms in exchange for money or something else, *i.e.* transactions take place. We have therefore found it useful to further classify primary business processes into transformation and transaction processes. This distinction makes it possible to model the allocation of primary processes to the supply chain participants involved. *Transformation Process*es are primary processes that contribute directly to the creation and movement of products by a company such as engineering, production and distribution. *Transaction Processes* are primary processes that contribute directly to the establishment and conclusion of transactions between two actors, in particular, sales and purchasing. Consequently, the business processes of a supply chain consist of a sequence of transformation processes that add value to the product and transaction processes that connect transformations of the involved partners.
The basic idea of *CONTROL* is the introduction of a controller that measures system behaviour and corrects if measurements are not compliant with system objectives (De Leeuw, 1997). A key factor that determines the variation of control systems is the position of the Customer Order Decoupling Point (CODP), also called order penetration point (Sharman, 1984, Wortmann *et al.*, 1997). The CODP separates that part of the supply chain geared towards directly satisfying customer orders from that part of the supply chain anticipating future demand (Hoekstra and Romme, 1992). Based on different CODP positions, different control strategies are proposed in literature, varying from strategies in which all processes are driven by customer order to fully anticipatory strategies in which all processes are based on demand forecasts. The main strategies proposed in literature are engineer-to-order (ETO), make-to-order (MTO), assemble-to-order (ATO) and make-to-stock (MTS). These control strategies particularly differ regarding the basis for production planning and engineering, the planning concept, structuring of product and process master data, and order entry/order promising (Wemmerlov, 1984, Giesberts and Tang, 1992).

COORDINATION mechanisms are studied in-depth in organisational science. (Thompson, 1967) distinguished three basic types of dependency: pooled, sequential and reciprocal interdependence, which require different types of coordination. Based on his work, which is refined by many others, three basic coordination modes can be defined: coordination by standardisation, coordination by plan (direct supervision) and coordination by mutual adjustment. Initially, the focus was on coordination between organisational subunits. However, (Malone and Crowston, 1994) argue that the primary source of coordination problems is dependence among processes using resources. They distinguish three basic types of such dependencies:

- *Flow dependencies* arise whenever one process produces a resource that is used by another process (precedence relation);
- *Sharing dependencies* occur whenever multiple processes use the same resource;
- *Fit dependencies* arise when multiple processes collectively produce a single resource.

Supply Chain Management (SCM) is primarily concerned with coordination of flow dependencies: the business process output of one actor is the input of another actor's processes. The main flows among supply chain business processes are products, orders, and demand and supply information. Besides these flow dependencies, there are some key dependencies among multiple flows in a supply chain. These are related to the common usage of resources, *i.e.* material and capacity. Appendix A summarises a classification of mechanisms to coordinate these dependencies in supply chains.

4 Toolbox for modelling business processes in demand-driven supply chains

The second part of the designed framework is a toolkit that can be used to configure three types of supply chain process models, *i.e.* Product Flow Models, Thread Diagrams and Business Process Diagrams. For each process model type, the toolbox contains i) standard model building blocks (reference components), ii) a method to instantiate diagrams of specific supply chain configurations (configuration trees), and iii) pre-configured models (reference templates) that capture reusable knowledge abstracted from the case studies.

Product Flow Models visualize the allocation of basic transformations to supply chain actors and the related product flows from input material into end products. The product flows among transformations comprise several levels of aggregation. Based on the GS1 Global Traceability Standard (Ryu and Taillard, 2007), four different units are distinguished:

1. *Shipping Unit (SU)*: an item or group of items delivered to one party's location at one moment in time, which undergoes the same dispatch and receipt processes. SUs can be identified with a standard Shipment Identification Number (SIN).
2. *Logistics Unit (LU)*: an item of any composition established for transport and / or storage that needs to be managed through the supply chain. LUs can be identified with standard Serial Shipping Container Codes (SSCC).
3. *Trade Unit (TU)*: product unit as it is traded before the point of sales in the supply chain. TUs can be identified with standard Global Trade Item Numbers (GTIN), in combination with a serial number (SGTIN) or with a batch / lot number.
4. *Consumer Unit (CU)*: product as it is sold to the end customer. CUs can be identified in the same way as TUs.

Thread Diagrams are used in SCOR to provide a process overview of the complete supply chain configuration in scope. However, the suggested technique does not provide sufficient representation power to model our object system as defined before. The essential differences in the underlying control systems and coordination mechanisms are not explicitly modelled. Therefore, we developed an alternative way of modelling supply chain Thread Diagrams, which depicts how order-driven and forecast-driven processes are decoupled in specific supply chain configurations (positions Customer Order Decoupling Points) and how interdependences between processes are coordinated. Basic reference components of such diagrams are business control cases and coordination mechanisms. A business control case represents a sequenced group of business processes that follow the same control strategy. Business control cases can be either responsive (to order) or anticipatory (to forecast). CODPs decouple series of responsive and series of forecast-driven control cases. A coordination mechanism manages the interdependencies among business control cases. Coordination of Product and Order precedence's (P/O) occur at every interface of two basic supply chain roles, *i.e.* when products are passed on from one actor to another according to an agreement about the requirements (order). Coordination of capacity usage, capacity precedence and material consumption (C/M) manages the dependencies among multiple control cases per actor. Last, the exchange of Demand and Supply information (D/S) connects anticipatory cases of a supplier with responsive cases of a customer.

Business Process Diagrams depict the sequence and interaction of control and coordination activities (as identified in Thread Diagrams). Business Process Diagrams can be composed by zooming in on specific business control cases or coordination mechanisms. The basic building blocks for process modelling are activities. These are adopted from the SCOR 3 processes although several refinements were implemented. Based on an in-depth analysis, it was found that these process definitions provide an appropriate repository of generic process building blocks for modelling supply chain configurations. The Business Process Diagrams are modelled in the Business Process Modeling Notation (BPMN) to ensure smooth translation of supply chain designs to information systems architecture (OMG, 2009). BPMN has developed into the de facto standard for business process modeling in Service-Oriented Architectures (SOA) and includes a mapping to the underlying web service execution languages, i.e. BPEL and BPML (see www.bpmn.org).

Next section illustrates the application of this framework by discussing case study results.

5 Applications to different agri-food sectors in case studies

The designed modelling framework is applied in different agri-food sectors, in particular potted plants and fruit supply chains. In this section, we highlight some findings of the fruit case study to illustrate application of the designed framework.
The case study has been carried out as part of the EU-Sixth Framework Integrated Project ISAFRUIT (www.isafruit.org). It builds on data collected in Work package 1.4 (INNOCHAIN) of Pillar 1, which focuses on the area of 'Consumer driven and responsive supply chain'. In total 8 supply chains in 4 European countries have been investigated, based on in-depth interviews with managers.

Table 1. Overview of the involved fruit supply chains

Coun-try	Product	Characteristics	Fresh	Prepared/ Processed
Poland	1.Fresh Apple	Main actor is a cooperative of 28 apple growers with a total production area of 230 hectares. Primary customer segment are about 250 of supermarkets and fruit shops in the Warsaw agglomeration. Additional market channels are wholesalers and exporters.	X	*
	2.Organic Fruit	Delivery organic fruits to local and international retailers, as well as organic food shops. The majority of the assortment comprises processed fruits such as juices, jams, dried fruit and muesli. It is a closed chain that is coordinated by a central orchestrator.	*	X
Greece	3.Fresh Apple	This supply chain comprises of 740 farmers, organized in a cooperative, that supply fresh apples to big local retailers, to exporters for foreign markets and to local wholesalers.	X	
	4.Canned Fruit	A joint venture of three cooperatives produces canned fruits (mainly peaches) for big international retailers, either directly or via importers. In total, 2200 farmers are member of the involved cooperatives and their cultivations cover about 3200 hectares.		X
Spain	5. Seedless Watermelon	Delivery of watermelons to supermarkets and fruit shops, mainly via wholesalers. The melons have a certified quality and they are seedless, which makes in particular appropriate for children.	X	*
	6. Fresh Stone Fruits	The main actors are a producer cooperative and a retailer cooperative. The producer cooperative produces fresh fruits of in total 3000 hectares. The retailer cooperative has supermarkets all over the country, 10 logistics platforms, 10 cash and carry stores that supply the food service segment and several providers of additional services.	X	*
The Nether-lands	7.Black Currant as Ingredient	Delivery of black currents as an ingredient of food products, in particular ice creams. The main actors are a cooperative of 28 growers, a pre-processing firm, a food processor and a retailer.		X
	8. Fruit Salads	This supply chain focuses on supply of fruit salads to a catering company. The caterer is part of a big multinational that is active in 80 countries. It has a five-year contract with a big local wholesaler dedicated to the food service industry.		X
		*Legend: X main focus, * sideline activity*		

The identified basic transformations in fruit supply chains are: Growing and Harvesting, Processing, Washing, Sorting and Grading, Packaging and Labelling, Storage and Distribution, and Retailing. The case study shows that there are many different allocations of these transformations to the supply chain actors, in particular fruit producers, fruit processors, traders (including importers and exporters), retailers and specialized service providers (i.e. packaging firms, transporters, and storage and transhipment firms). In the reference model, different template Product Flow Models are pre-configured in order to cover the basic variety in these allocations. Figure 2 depicts one of these templates and visualizes the production and delivery of pre-packed apples to a fruit specialist shop.

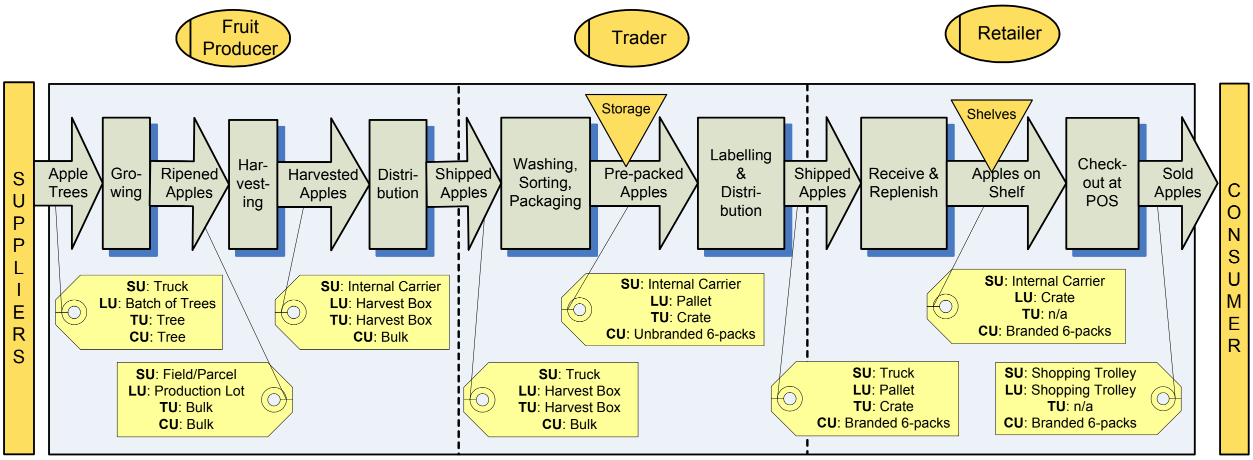

Figure 2. Template Product Flow Model fresh hard fruits for fruit specialist shops

In this Product Flow Model template, the fruit producer grows the apples, harvests ripened apples in cubic boxes, and ships the harvested apples to a trader. The trader washes, sorts and packs the apples in unbranded 6-packs. The pre-packed apples are stored until they can be delivered to a specific retailer. Then, the apples are labelled with the retailer's brand and shipped directly to local fruit specialist shops. The shop receives and replenishes the shelves. Finally, consumers pick the 6-packs from the shop shelves and check-out at the Point of Sales (POS). Figure 2 depicts these basic transformations, including the related product flows. The labels describe the logistics units of the product flows, *i.e.* the shipping units (SU), logistic units (LU), trading units (TUs) and consumer units (CUs).

Besides the allocation of transformations in the supply chain network, the variety of the investigated supply chain configurations are determined by the extent to which fruit chains are order-driven. The investigation shows that configurations of fruit supply chains can be positioned in a continuum from anticipatory (push) to order-driven (pull). We modelled typical supply chain configurations for both fresh and processed fruit as template instantiations of the modelling framework developed in this paper. One of these configurations is a fresh fruit supply chain in which a trader buys the complete yield of a certain year and stores in a controlled atmosphere warehouse. He delivers the fruit on demand to a retailer. Figure 3. Example of a configured Thread Diagram for a Fresh Fruit Supply Chain3 depicts the Thread Diagram is this supply chain configuration.

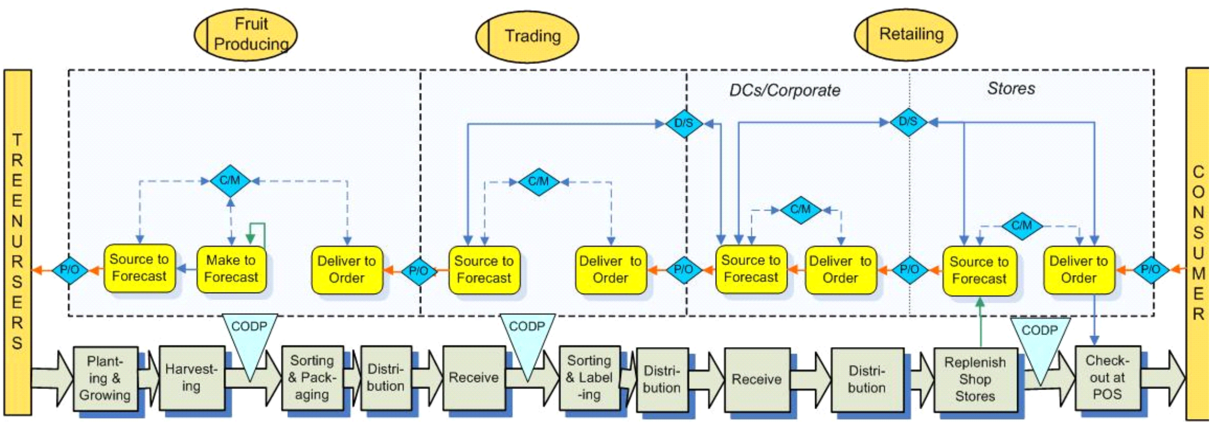

Figure 3. Example of a configured Thread Diagram for a Fresh Fruit Supply Chain

The involved contributors are presented at the top of the figure. At the bottom, the basic processes are visualised that transform fruit trees and other input material into fresh fruit on the supermarket shelves. CODPs (the triangles) indicate to what extent these transformations are order-driven. Checkout at the Point of Sales is driven by consumer orders. The trader receives combined orders of all local stores and distributes the requested fruits to the retailer's distribution centre. The fruit grower produces and harvests to forecast. Next, the centre of the diagram depicts a network of business control cases (the rounded rectangles) and coordination mechanisms (the diamonds). They are defined in terms of the generic SCOR processes, source, make or deliver, and can be either responsive (to order) or anticipatory (to forecast). Also the coordination mechanisms that manage interdependencies among business control cases are defined in generically as described in previous section.

Detailed Business Process Models can be configured by zooming into a process case of the supply chain Thread Diagram. For example, following the configuration tree as introduced in previous section, the Business Process Diagram of the case "Deliver to order" of the grower (see Figure 3. Example of a configured Thread Diagram for a Fresh Fruit Supply Chain3) can be configured as visualized in The involved contributors are presented at the top of the figure. At the bottom, the basic processes are visualised that transform fruit trees and other input material into fresh fruit on the supermarket shelves. CODPs (the triangles) indicate to what extent these transformations are order-driven. Checkout at the Point of Sales is driven by consumer orders. The trader receives combined orders of all local stores and distributes the requested fruits to the retailer's distribution centre. The fruit grower produces and harvests to forecast. Next, the centre of the diagram depicts a network of business control cases (the rounded rectangles) and coordination mechanisms (the diamonds). They are defined in terms of the generic SCOR processes, source, make or deliver, and can be either responsive (to order) or anticipatory (to forecast). Also the coordination mechanisms that manage interdependencies among business control cases are defined in generically as described in previous section.4.

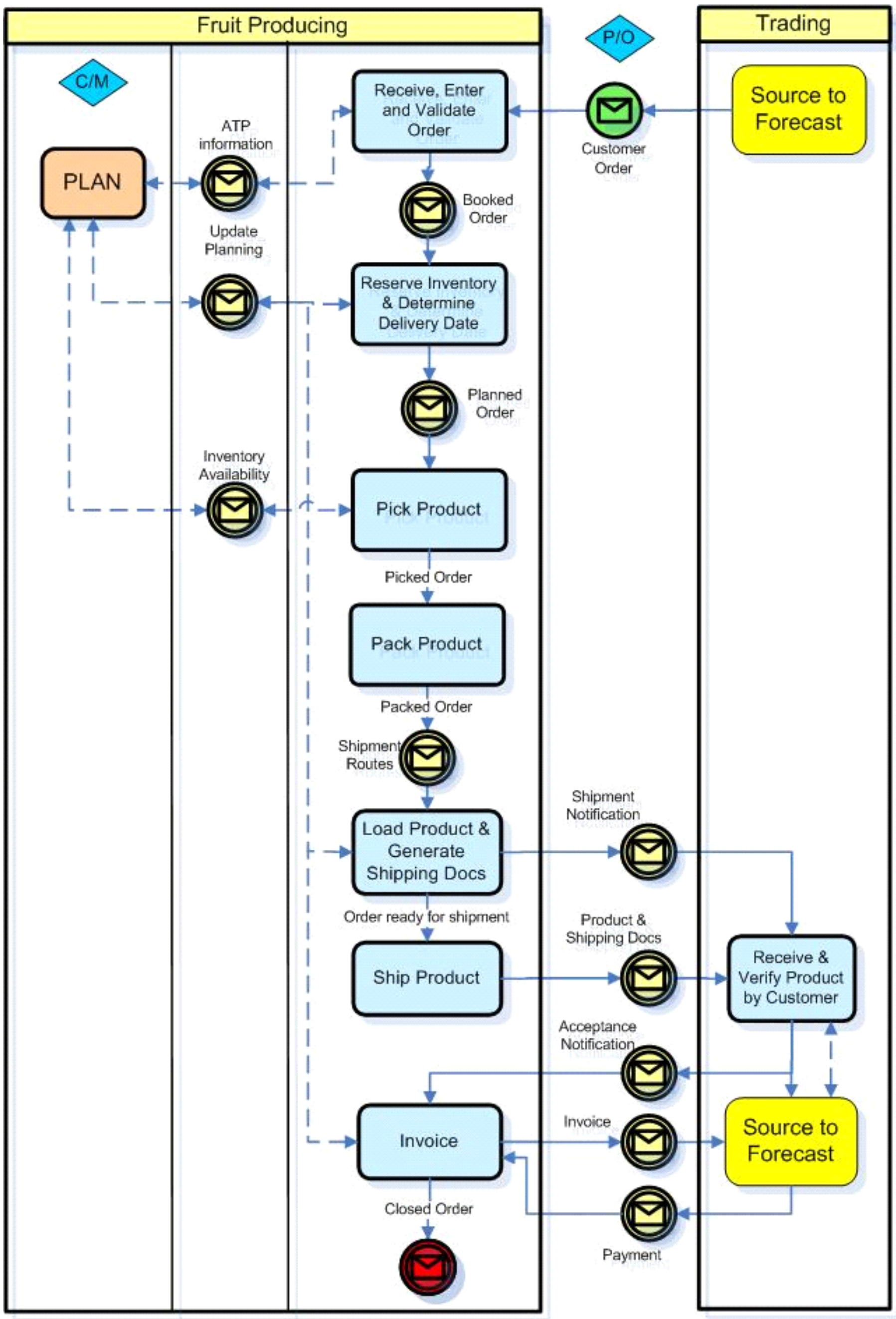

Figure 4. Example of a configured process model for Deliver to Order

The figure shows the Business Process Diagram of order-driven delivery by a fruit producer to a trader in three interacting lanes. It is triggered by an order request from the trader, who sources to order. The process flow at the centre of the diagram depicts the activities for further processing, starting with order receipt. The activities match to the SCOR level 3 processes. The interactions with other processes are shown in the events with external business control cases. The type of coordination of these interactions is visualized at the top of the lanes. These coordination mechanisms, as well as the connections to external business control cases, are compliant with the parent supply chain Thread Diagram.

Above, we have introduced a modelling framework for designing reference process models in demand-driven agri-food supply chains and illustrated the application of the framework by discussing some of the case study results. To conclude, next section discusses the implications for policy and business.

6 Business and policy implications

This paper has introduced the design of a framework for reference process modelling in demand-driven agri-food supply chains. Although the use of the framework is not limited to demand-driven supply chains, it is particularly useful in the case of a high variety and variability of supply chain configurations as apparent in demand-driven supply chains. The main value of the framework is that it helps to map, in a timely, punctual and coherent way, the business processes of the supply chain configurations that a company must manage in order to fulfil the different demand requirements of their customers. More specifically, three benefits can be distinguished.

First, the process framework comprises a consistent set of supply chain models that are on the one hand understandable for business managers and on the other hand serve as a basis for information system implementation. As a result, it intermediates between supply chain design and information systems engineering.

Second, the framework supports the modelling of a broad variety of process configurations as apparent in agri-food supply chains. It contains a systematic classification of required building blocks, a method that describes how specific configurations can be composed from these building blocks and pre-configured templates of typical configurations in agri-food supply chains. Contrary to most of the existing supply chain models, our framework does not prescribe a strict blueprint of the 'best' supply chain design (no one size fits all), but it enables a rapid instantiation of various supply chain configurations from a repository of standard building blocks.

Third, the framework combines agri-food-specific knowledge with reuse of knowledge provided by generic standards, in particular SCOR. By doing so, it builds on a broadly accepted modelling language for supply chain design and thus it enhances shared understanding. It also implies that both cross-industry and sector-specific process knowledge is reused.

The designed framework is based on case studies in several agri-food sectors and reviewed in-depth by industry experts. As a result, the research provides solid evidence that the framework meets the specific requirements to reference process models in demand-driven agri-food supply chains. Nevertheless, we foresee some important opportunities for future development and research. It should be further assessed how the framework can be used to implement integrated information systems in supply chains. The configuration of process models in the framework should be supported by software tools. It could be researched how to extend the framework to business processes such as strategic planning, product development and (collaborative) innovation and marketing.

However, the first next step should be to embed the framework in such a way that business-driven development is ensured while keeping the model manageable and robust. To achieve this, it is necessary that the present framework functions as a basic design, which is further developed iteratively by pilots, based on business cases to provide proof of concepts (*cf.* (Wolfert *et al.*, 2010). The pilots should use the basic design as a frame of reference to develop specific reference business process models. By using the basic design as a starting point, consistency and robustness of single pilots, as well as the reuse of existing knowledge is ensured. Next, the basic design can be used as a core vehicle to abstract reusable knowledge from the pilots. This ensures that the results can be re-used in other pilot projects.

Thus, the framework grows incrementally and knowledge is built up and reused by its application.
Agri-food firms could implement the framework individually. Major disadvantages are that in this case implementation experiences are not exchanged among firms and maintenance costs are not shared. Moreover, ensuring compliance with international standards and cross-industry model and further development might exceed the level of single firms. Therefore, successful adoption and application of a reference modelling framework implies arrangements at different institutional levels:

- *industry-wide*: one central institution that is coordinating industry-wide framework development and maintenance, managing alignment with relevant international standards, supporting knowledge exchange within a sector, continuously monitoring the developments out of the industry and bringing in useful knowledge in cooperation with universities and research institutes;
- *coalitions*: cooperating companies, including service providers, research institutes and governmental organizations, that come to terms with specific subjects and develop new solutions in pilots based on the industry-wide framework;
- *individual organizations*: especially farmers, processing companies, and software companies that actively participate in coalitions and adapt their products to the agreed standards.

The different tasks, associated with these activities, can be allocated differently to these organizational levels. Several experiences, among others in Dutch arable farming, have learnt that a central organization should not be organized too 'heavily'. A network-coordinated organization with small staff is preferable. Such a dynamic organization should focus on sector-specific standards (small part of the total required standardization) and on providing services to coalitions related to adoption of external standards and usage of external knowledge. The various actors also have to get used to different roles. Software engineers are no longer in the lead of the developing process and often have to get used to the business modelling approach. The framework implies more use of standards and re-use of public domain software services within a service-oriented architecture. This means that vendors can rely less on their own-developed software. Business managers have to get used to deeper involvement in the information systems engineering process and to communicate more with ICT experts than they were used to. Researchers and consultants can play an intermediating role in this. To a certain extent, they must have insight into the business processes and usually they are the ones safeguarding the soundness of the architecture. They are expected to supply the state-of-the-art knowledge from research, but have to get used to the requirement that it must be directly applicable in a practical environment and not only in a laboratory setting. Open innovation implies common development of concepts and products. This requires new agreements between different stakeholders on intellectual property rights. Experiences so far learned that, in the beginning, people thought that they had a very unique concept, idea or application. By cooperating in the new setting, they gradually left this thought and placed it into the public domain. This was enhanced by the advanced insight that if everybody within a specific sector exhibits a more open innovation approach, the sector as a whole will benefit from it.

To conclude, the open innovation approach in further development and maintenance of the designed framework will result in important industry-wide benefits in the long term. However, from the perspective of single firms, the own added value in the short-term in relation to the additional efforts of an open approach is not always obvious, although the pilot approach helps. Policy makers could play an important role in lowering these barriers by:

- Stimulating awareness and commitment for adoption of process thinking, reference models and standard, and open, user-driven innovation and research;
- Financing the basic design, on-going development and maintenance, including the incorporation of important social issues such as food safety, animal welfare, and sustainable use of resources,
- Ensuring the compliance with national and international legislation and supporting harmonization with relevant international standards.

Appendix A: Classification of supply chain coordination mechanisms from a business process perspective

Dependency	Type	Coordination
Product Precedence	Flow	Products produced by supplier companies are input for customer firms downstream in the supply chain. Therefore, input products (raw or semi-finished, packaging and handling unit for internal logistics) must have the appropriate characteristics, they must be in time and at the right place. Mechanisms to coordinate this include adopting product and logistics standards, negotiating product specifications, standard product delivery frequencies, distribution requirements planning and standard distribution network layouts.
Order Precedence	Flow	Customer orders are conditional for execution of order-driven processes. Therefore, the customer requirements as specified in an order must match with the available supply chain capabilities. In other words, the requested products and associated service levels must be available to promise (ATP). Next, the order format must be appropriate for further processing. Mechanisms to coordinate this are adopting order standards, enforcement of order content and mutual adjustment until order information is complete. Furthermore, order information must be available in time at the right location. Mechanisms to coordinate this include standard order windows and planning of order submissions based on integrated planning systems.
Demand Information Precedence	Flow	Demand information of customers is used as input for forecasting processes of suppliers upstream in the supply chain. Therefore, customers' demand information must be appropriate for suppliers' forecasting process (usability) and it must be available in time at the right place. Corresponding coordination mechanisms include agreeing on a standard frequency and format of exchanging Point of Sales (POS) and decentralised completion of demand information.
Supply Information Precedence	Flow	Firms downstream in the supply chain use information about current and future availability of input products as a basis for planning and sales. Similar to demand information, supply information must also be appropriate for processing (usability) and it must be available in time at the right place. Besides these flow dependencies, there are some key dependencies among multiple flows in a supply chain. These are related to the common usage of resources, *i.e.* material and capacity.
Material Consumption	Sha-ring	Multiple processes all use the same input products which can be used only once. Coordination of this dependency demands alignment of required input material for different end products. Coordination mechanisms include standard allocation rules (such as First-Come-First-Serve, market-like bidding or priority order), centralised material requirements planning or reservation by negotiation and informal communication.
Capacity Usage	Sha-ring	Processes for multiple customer orders all use the same limited c apacity. Similar to material consumption, this dependency can be coordinated by standard reservation rules, centralised capacity requirements planning or reservation by mutual adjustment.
Capacity Precedence	Flow	Required capacity must be available for execution of (both order and forecast-driven) transformation processes. Therefore, capacity must meet the required service level. Important mechanisms to coordinate this are standard Service Level Agreements (including standards service and maintenance windows) and centralised or synchronised resource planning.

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